UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

THE MAT BEAN
PHASEOLUS ACONITIFOLIUS

P. B. KENNEDY AND B. A. MADSON

BULLETIN 396

NOVEMBER, 1925

UNIVERSITY OF CALIFORNIA PRINTING OFFICE
BERKELEY, CALIFORNIA
1925

Digitized by the Internet Archive
in 2012 with funding from
University of California, Davis Libraries

http://www.archive.org/details/matbeanphaseolus396kenn

THE MAT BEAN*

(*Phaseolus aconitifolius*)

P. B. KENNEDY AND B. A. MADSON†

INTRODUCTION

Several years ago our attention was called to the need of a summer legume which would combine several qualities not found in any one of the legumes in general use at that time. In some vineyards and orchards, there was need for a leguminous green manure crop which, by protecting the soil from the hot sun, would prevent the burning out of organic matter and yet leave the irrigation furrows visible and accessible. On unirrigated grain lands, moreover, there was a need for a drought tolerant legume, which would provide pasture and improve the soil, and which could be rotated with grain.

The mat bean, a plant growing in the rod-row trial garden of the Division of Agronomy at the branch experiment station at Kearney Park, seemed to fill both of these needs. Its creeping habit and low growth made it promising as a cover and green manure crop which would not interfere with the irrigation and harvesting of the fruit crops. It seemed promising as a pasture crop because of its drought tolerance and the fact, determined during the investigations, that livestock graze on its foliage and pods with avidity.

In India, the green pods are eaten as a vegetable and the tiny beans, about the size of rice grains, are also used to a considerable extent for human food. These beans, being small and high in protein, are especially suitable for poultry.

HISTORY AND ORIGIN

The mat bean is to be found in its wild state in India from Ceylon to the Himalayas, a distance of some 1500 miles, ascending the hills to an elevation of 4000 feet, especially in the northwest. De Candolle[1]

* The writers desire to express their appreciation to Messrs. J. A. Denny, V. H. Maghetti, and L. Beaty, foremen of the branch field experiment stations at Kearney Park, Davis, and Meloland respectively, for their interest in conducting the field trials with the mat bean. We are also indebted to Mr. Harold Goss, junior chemist in the Agricultural Experiment Station, for some of the analyses.

† Div. of Agronomy.

states that the absence of a Sanskrit name for it and the different names applied to it in modern Indian languages indicate that it has been brought into cultivation in comparatively recent times. In the Bombay Presidency it is known as mat or matki. The Sikhs call it moth, pronounced more like mote, and the Hindustani name is mout. Ghosh uses the name bringhi. Other Indian names are math, banmunga, kheri, bir mung, mattikalai, tulka, kuncuma-pesalu. As there are more than one hundred dialects in India and the plant is cultivated over an extensive area no doubt the vernacular names are very numerous. German works (Harz[6]) call it "Die eisenhutblatterige Bohne," meaning the bean with leaves like those of aconite. The name "moth," one of the Indian synonyms, has nothing to do with the English word, moth, either in meaning or pronunciation. The "th" represents a sound unknown to English. We have adopted the name "Mat," used in the Bombay Presidency, because of its appropriateness in the English language to represent the habit of the plant of forming a *mat* on the ground.

That the mat bean is a well established commercial crop in India may be gathered from a few instances where the acreage grown has been recorded. Mollison[11] gives the acreage as 300,000 for Bombay; Duthie and Fuller[4] give 211,000 for the North-Western Provinces and Ouhd. In the United Provinces, together with urd, mung and cowpeas it occupied 1,062,783 acres in the season of 1904-05. Mollison[11] states that this legume is fourth in importance in India and that it is grown to a considerable extent in all the districts except the Konkan.

The classification of agricultural crops in the Agricultural Statistics of India is too general to supply exact data in regard to the acreage growing any particular bean, but it is evident, that several million acres are annually devoted to the mat bean alone and in mixtures with other crops, especially millets and sorghums.

Piper and Morse[12] mention that eight lots of mat bean seed were obtained from India by the United States Department of Agriculture. The first introduction appears to be Seed and Plant Introduction No. 8539 received on April 1, 1902, from Poona, India, accompanied by the following note from the Department Agricultural Explorer, Dr. S. A. Knapp: "Math." This legume is grown in the Deccan and the Gujarat as a 'Kharif,' or rain crop, sown only in the rainy season. It does well on light, stony, upland soil with an average rainfall of 30 inches."

The origin of our mat bean as grown in California is Seed and Plant Introduction No. 21600, grown at the Agricultural Station at Dhulia, and sent from Poona, Bombay, India, by Mr. F. Fletcher,

Deputy Director of Agriculture. It was received at Washington, D. C., on November 26, 1907. This introduction represents mainly a yellow seeded variety but a considerable number of seeds of a black mottled variety may be observed on careful examination.

GENERAL DESCRIPTION OF THE PLANT

The mat bean is an annual, summer legume creeping and trailing over the ground from branches arising from a central stem (see fig. 1). The main stem is erect and short (about 6 to 8 inches in height)

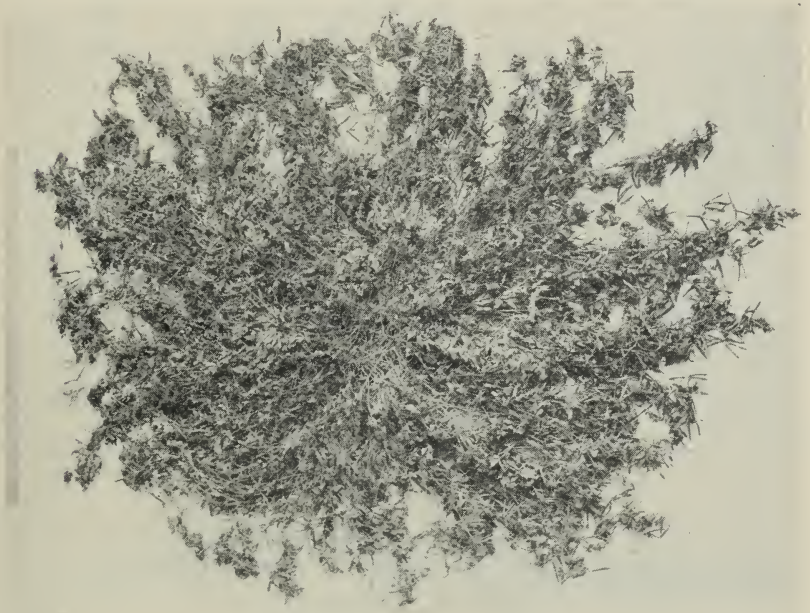

Fig. 1.—Three mat bean plants "matted" together covering an area of about twenty square feet of ground. University Farm, Davis.

from which are produced horizontal branches (see fig. 2) that radiate to a distance of from two to five feet, according to conditions. All parts of the plant are sparsely covered with hairs which are at first white but soon turn a rusty brown. The hairs on the pods are very short and stiff.

By its leaves the mat bean can be distinguished from all other cultivated beans. They consist of three leaflets (see fig. 3), each divided into from three to five pointed lobes. They resemble the leaves of the aconite plant and hence the name aconite-leaved kidney bean, sometimes applied to the mat bean.

The leaf stalks (petioles) are at first longer than the flower stalks (peduncles) but as the season advances the reverse is generally true. Usually there is only one flower stalk arising from the axil of each leaf but this stalk may occasionally develop two or three branches. The length of the flower stalk varies from 1½ to 3 inches and is terminated by from 1 to 6 small (¼-in.) bright yellow flowers. From these may develop from 1 to 6 pods (usually three).

The pods (see fig. 3) are of a rusty brown color when mature, from 1 to 2 inches long and about $\frac{1}{10}$ of an inch wide. The number of seeds to a pod is from 4 to 9, the most frequent number being six. Our plants of No. 21600 produce tan-colored seeds (see fig 3) mixed

Fig. 2.—A trailing branch of a mature mat bean plant. Kearney Park, Agronomy Field Station. November 7, 1922.

with many black-mottled seeds of a different variety. They are small and cylindrical, probably the smallest of the kidney beans, as they are only about $\frac{1}{6}$ of an inch long and less than $\frac{1}{8}$ of an inch wide. The scar or hilum is white, less than $\frac{1}{16}$ of an inch long, and usually centrally or laterally placed. The seed weighs 65 pounds to the bushel.

The black mottled variety, according to Ghosh, has slightly larger seeds and gives a heavier yield of forage than the yellow seeded variety. This indicates that it would probably be advantageous to establish the black mottled variety. In India the yellow and mottled strains are not usually separated commercially. We have separated the two types of seed found in No. 21600 and are growing them separately this season. As the flowers are normally self fertile it should not be a difficult matter to establish any particular strain desired.

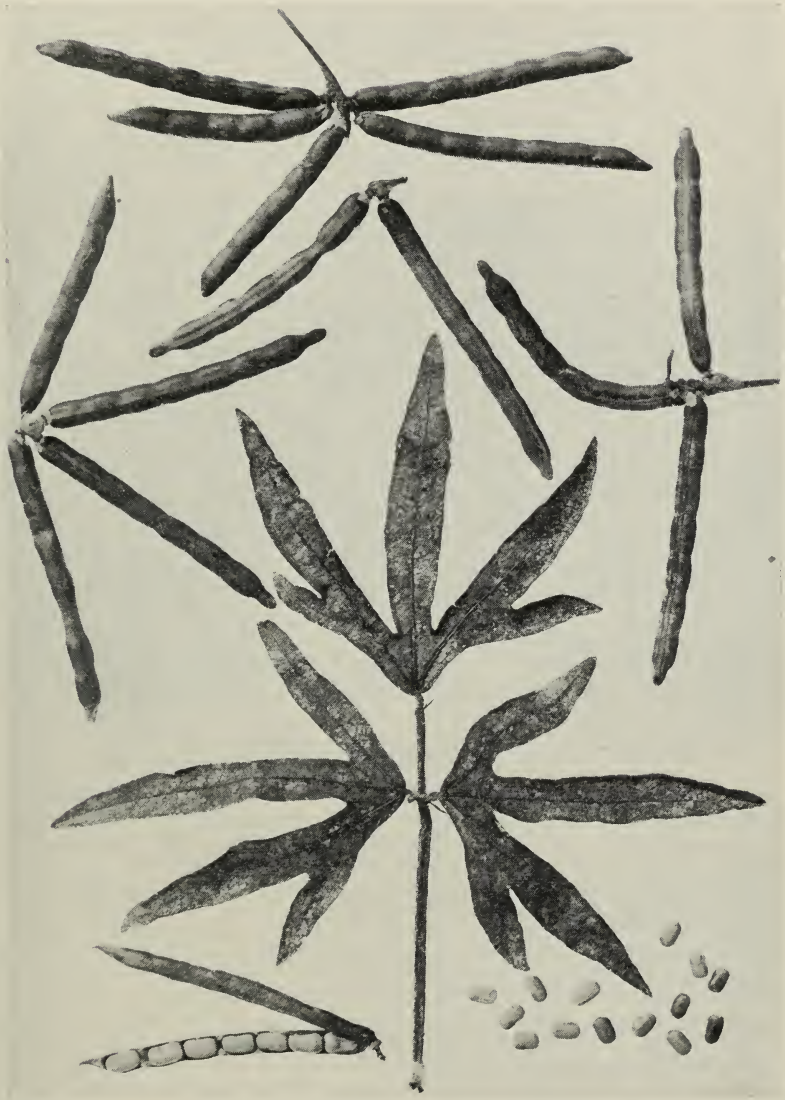

Fig. 3.—A single leaf with its three lobed leaflets. Seed pods and seeds.

BOTANICAL DESCRIPTION

Phaseolus aconitifolius. Plant annual, main *stem* suffrutescent, short (about one foot), erect, with primary, secondary and tertiary horizontal trailing branches. Primary branches (fig. 2) about twelve, 2–5 feet long, secondary about twenty-five, 2 feet long, and about twelve tertiary ones about 1 foot in length. All parts of the plant covered with whitish hairs which turn a rusty brown with age. *Stem* and branches angular and flexuose. *Internodes* of main stem short (0.5–1.0 inches) with those of the branches longer (1–3 inches). *Leaves* alternate, 3-foliolate, about 2.5 inches long, the central terminal leaflet slightly larger than the two lateral ones. Terminal *leaflet* usually divided into 5 acuminate lobes, lateral leaflets 4 lobed. *Petioles* canaliculate, 2–4 inches long. *Stipules* peltate with oblong-lanceolate to linear-lanceolate lobes, 0.5 inch long and 0.1 inch wide. *Stipels* at base of leaflets, subulate, about .2 inch long. *Inflorescence* arising from the axil of each leaf at an angle of about 60 degrees with the stem in the form of a long-peduncled capitate raceme of several small yellow flowers. *Peduncles*, longer or shorter than the petioles depending on the stage of growth of the plant: only one peduncle from each leaf axil, but occasionally appearing as three by the branching of the main peduncle. Length of peduncles 2–4 inches. Flower bracts and bracteoles small, subulate, caducous: *Rachis* very short (.3–.7 inch long), glandular, *pedicels* about .1 inch long. Flowers yellow (.3 inch long and .2 inch broad), *calyx-tube*, .1 inch long, *calyx-teeth* 5, the two upper short and broad, the three lower narrower and acuminate; *vexillum* (standard), pale yellow reniform, broadly emarginate at the apex, minutely pubescent, ventricosely downward pointed forming a hood; *wings* bright yellow, left one spirally coiled around the keel, right one slightly twisted enclosing the keel; *keel* twisted; style, twisted, stigma flat, bearded on the lower side, ovary minutely hirsutulous. Stamens 10, nine forming a sheath and one free. Mature legume (pod), (fig. 3) small, 1–2 inches long and .2 inch wide and .1 inch thick, with short curved beak and covered with short stiff bristles, buff to yellowish brown, 4–9 seeded. Seeds (fig. 3) small, .2 inch long and .1 wide, cylindrical, somewhat reniform, rounded or truncate at the ends. Color of seeds in ours (No. 21600) a light tan with a pinkish tinge. In other strains the seed may vary from dull yellow to brown or black mottled. *Hilum* linear white, less than .1 inch long.

RELATED SPECIES

Five additional oriental beans[12] that might be considered as similar in their climatic and soil requirements are, the adsuki bean (*Phaseolus angularis*), the rice bean (*Phaseolus calcaratus*), the mung bean (*Phaseolus aureus*), the urd (*Phaseolus mungo*), and the meth bean (*Phaseolus ricciardianus*). All of these except the last mentioned, the meth bean, have been grown for a number of years in our experimental gardens. We have been unable to find any record of the meth bean having been introduced into the United States, although it is said to be grown extensively in high alluvial lands adjoining rivers and in the partially shaded lands of orchards in some parts of India. It is generally sown in mixtures with sorghum or maize at the time of hoeing these crops. The chief use made of it is as green fodder. When the seeds are used for human consumption they are reported to be very heating and to cause indigestion. When sown alone its habit of growth is very similar to that of the mat bean, having a short erect main stem, from which arise laterally, extensively creeping vines. When stakes or an erect crop like maize or sorghum is provided the vines reach a considerable height by twining.

The adsuki bean is the favorite bean in Japan and commands a higher price than any other bean. Generally speaking it is to be compared with the bush varieties of our common bean (*Phaseolus vulgaris*), both as to climatic requirements and uses. According to Piper and Morse[12] the adsuki bean has a wide range of usefulness, being exceedingly popular as food among the Japanese and Koreans. They are used as bean meal in soups and gruels and for cakes and

confections in a manner similar to pop-corn, as a coffee substitute; and the flour for shampoos and facial cream. In texture the meal is superior to that of any other bean and the flavor is very delicate. The green pods have a tendency to become fibrous and are not desirable as snap-beans. There are numerous varieties, differing mainly in the time they take to mature and the color of the seeds. From the results of the experiments with adsuki beans in the rod row trials we were not encouraged to make larger plantings as a number of other summer legumes make better crops for green manure or forage. However they made an excellent stand and a heavy growth, 24 to 26 inches in height, and as they are good seed producers it is quite likely that they may become important beans for human consumption.

The rice bean is cultivated to a limited extent in Japan, China, India and the Philippines.

It is an annual plant, half twining in habit, growing about two feet high with spreading vines from 3 to 6 feet long and bright yellow flowers. With us it has proven very late and a poor seed yielder. The pods split and shatter the seed as soon as ripe. We have not found it sufficiently promising to extend the trials beyond the rod rows.

The mung bean[8] is one of well-known oriental beans which has been cultivated in India from very early times, the seeds being used for human food and the straw as forage for cattle. It is not uncommon to find mung beans in the United States in Chinese restaurants. The favorite method of utilizing them is by sprouting the seeds in the same manner as we do oats for poultry. These sprouts resemble vermicelli and are cooked in various ways.

The plant resembles our common bush types of garden or field beans but generally with smaller leaves. It grows erect with many branches and may reach a height of four feet. We have had no difficulty in growing it as a summer legume but it enters into direct competition both as a forage and as a green manure with the cowpea. It has an advantage over the cowpea in that, the seeds being much smaller, the rate of seeding is much less, about four pounds per acre. Their small size, much smaller than garden peas, make them more desirable for pigeons or poultry.

We have grown a number of different strains and find a great variation in the time of maturity, those which we designate as Hasting's mung and Kearney mung being our most promising strains.

The urd is similar to the mung and is used quite extensively in India. The growth is shorter than the mung and the yield of herbage much less. We have not experimented with it outside of the rod row trial garden as it did not give promise for forage, cover crop or seed over other legumes.

ADAPTATION

Climatic Requirements.—The mat bean is a tropical plant and does best in regions having a high uniform temperature during the growing season. During the seasons 1923 and 1924 it has grown very satisfactorily at the three experiment stations; i.e., Meloland, Imperial Valley; Kearney Park, Fresno (see fig. 6); University Farm, Davis. At Davis, however, the growth has been slower than at the other two stations and the plants require the full growing season to reach maturity. This apparently was due to the lower temperature which prevails at Davis. These results would indicate that the crop is well adapted to the warmer sections of the interior valleys, and perhaps to the whole of southern California, but that it would not do so well in the coastal valleys, nor in sections where the growing season is short,

or the temperature lower. In fact, it appears to be adapted to the same general climatic conditions as the cowpea, preferring if anything, a little more heat.

In the Imperial Valley it has not set seed as prolifically as at Kearney Park, or Davis, which may be due to the excessively high temperature at the former station during the blooming period. We know that fruiting of our common species of Phaseolus is affected adversely by high temperature, and it is possible that the mat bean is similarly affected, only to a less degree. At any rate, it has produced seed abundantly at both Kearney Park and at Davis.

The mat bean is reported to be quite tolerant of drought, but unfortunately our knowledge on this point is still rather limited. Based on observations made in northern Texas, Piper[13] states: "So far as can be ascertained in limited experience with it, it is somewhat more drought-resistant than the cowpea." Our experience to date would indicate that the mat bean is as drought tolerant as the cowpea.

At the Kearney Park station in 1923, when grown on loam soil, the growth and yield on the unirrigated plot was just as good as on the plots which received two irrigations during the growing season. At the same station in 1924, the mat bean with a number of other legumes, was planted on poor sandy soil, of such low water holding capacity, that satisfactory growth with any crop can be obtained only when frequent irrigation is provided during the growing season. The tract was irrigated some time before planting, but when the crop was put in, the seed bed was so dry that a poor stand was obtained. The mat beans which did appear, however, made a fair growth and at the time they were plowed under in September were in a normal, healthy, thrifty condition, while the other legumes, including the cowpea, were either dead or badly stunted by drought. Our experience at Davis, in 1924, was similar. Owing to the absence of spring rain, the seed bed dried out to such an extent that it was necessary to plant extremely deep, resulting in many of the plants dying before reaching the surface. The plants which came through, however, and established themselves did not seem to be hampered in their growth because of drought. On unirrigated land, getting the crop started appears to be the most difficult problem. The seeds are small and cannot be planted very deep, and in the absence of spring rains it is difficult to hold the moisture near enough to the surface to germinate the seed and get a good stand.

Soil Requirements.—According to Ghosh,[5] in India, "the plant thrives on all upland soils, either light sandy loams or heavy clay loams, without any application of manures." In this state it has made a

good growth on the "hard land" at the Imperial Valley station, on the silt loam at Davis, and on the heavy loam soils at Kearney Park (see fig. 6). Near the last station, a fair growth has been obtained on very poor sandy soil even under adverse conditions. It is safe to say that it can be grown on any good agricultural soil, provided the seed bed is well prepared and the climate favorable.

CULTURE

The methods of preparing the land, and the cultivation required in the production of the mat bean, will obviously vary with the locality, seasonal conditions, the character of the soil, and whether it is grown on dry land or with irrigation. The purpose for which the crop is grown will also influence to some extent the cultural methods employed. In common with other bean crops, the mat bean will respond to good treatment. Good physical condition of the soil and a well-prepared seed bed are more important than high fertility.

Preparation of the Seed Bed.—Since the seed of the mat bean is small and cannot be planted very deep, a good seed bed is particularly important in order to get prompt germination and a good stand. The most desirable seed bed is one in which the soil to a depth of several inches is firm, but friable, and moist, with a shallow rather well pulverized mulch on the surface. To secure such a seed bed, the best procedure is to plow the land rather deep in the fall or early winter, and leave it exposed in the rough to the winter rains. Then in the spring it should be cultivated sufficiently with surface tillage implements to keep down the weeds and maintain the mulch. Spring plowing is never as desirable as winter plowing and is particularly to be avoided when the crop is to be grown without irrigation. Land which is plowed after most of the winter rains are over, usually remains loose and open, dries out rapidly or becomes so rough and lumpy that a good seed bed cannot be prepared. These difficulties are ordinarily more pronounced if the soil is heavy than on the light sand or sandy loam soils, which are more friable and easier to work. There will be, of course, many situations when spring plowing is absolutely necessary, but it should always be as shallow as conditions will permit, and the plow should be followed immediately with surface tillage implements to repack the soil and fine the surface.

When the mat bean is to follow a winter annual, late spring planting must ordinarily be resorted to, and in most cases also it is necessary to irrigate before plowing, in order to put the soil in condition to work properly. Even though the land is worked down as soon as

plowed, it frequently happens that the soil will dry out to the full depth of plowing. In such cases it may be necessary to give the land a second light irrigation, and then rework the seed bed and plant the crop as soon as possible.

Time of Seeding.—The mat bean is a warm weather plant and should not be planted until the soil and atmosphere are quite warm. The seed is quite soft and if planted in a soil that is cold and uncongenial it rots easily. Furthermore, the plants which develop under such conditions are stunted in their growth and never attain the vigor of those which have germinated under more favorable circumstances and maintained a rapid growth from the start.

Germination tests at different temperatures, carried on by Mr. Harold T. Pence, a senior student in the College of Agriculture, showed under laboratory conditions, that the mat bean seed germinates quite readily at temperatures as low as 20°C. (68°F.) but that the rate of germination and the rate of elongation of the germ was much slower than at the more favorable temperature of 27°C. (80.6°F.). At the lower temperature, the sprouts were only a few millimeters in length or just breaking through the seed coat at the end of forty hours; while at the higher temperature they had attained an average length of 25 millimeters in the same period of time. When the rate of germination is reduced by low temperatures, more time is required for the shoots to reach the surface of the ground and most of the reserve food material in the seed will be used up before the seedlings become established. To secure some information, based on actual practice, on the optimum time of planting, a date-of-planting test was conducted at Kearney Park Station in 1923. In this test, plantings were made at intervals of approximately two weeks from April 23rd to July 6th. The results of this test are given in table 1.

TABLE 1

DATE OF PLANTING TEST, KEARNEY PARK, 1923

Date planted	Estimated stand	Yield of green matter per acre	Yield of seed per acre
	Per cent	*Tons*	*Pounds*
April 23	45	26.62	1647
May 3	25	20.37	1647
May 15	25	13.73	1173
June 2	35	9.19	969
June 15	50	12.22	650
July 6	90	13.19	280

While the stand was quite variable, primarily because of variations in the moisture content of the seed bed, the results obtained were striking. Much the higher yields of green matter were obtained from the earlier plantings, the decrease in the later plantings being marked though not uniform.

The variation in yield of the last four plantings may be due in part to the variation in stand, but it should be noted that the May 15 planting, with only 25 per cent of a stand, produced a higher yield of green matter per acre than did the July 6th planting with almost a perfect stand.

The yield of seed was the same for the first two plantings, but declined uniformly and rapidly thereafter, only about one-sixth as much seed being produced by the July 6th planting, as by the planting made on May 3rd. Here again, it is possible that the variation in stand may have influenced the results somewhat, since it has been observed that when the stand is heavy and the plants crowded, the tendency to produce seed is much reduced. In this test, however, the differences are too great and too uniform to be accounted for on this basis. Furthermore, other observations have shown, that the highest yield of seed will invariably be obtained, if the crop is planted as early as conditions will permit. A similar test was undertaken at the University Farm, at Davis, in 1924, four plantings being made at intervals of two weeks, beginning May 1st. Unfortunately the growth of the various plots was seriously vitiated, by an adjoining row of trees, so that no yield data was obtained. Nevertheless, some important observations on the effect of time of planting, on stand and growth, were made. It was observed that the time required for emergence of the plants was longer, and the ultimate stand poorer, on the plantings made May 1st and May 15th, than on the plantings made June 1st and June 15th.

Since in 1924, the spring was rather cold and backward, these observations do not mean that it was unsafe to plant the crop until June 1st, but rather emphasize the fact that it is difficult to get a good stand unless planting is delayed until the soil has warmed up thoroughly. On the other hand, the last planting, on June 15th, made less growth than the earlier planting and failed to mature before the advent of fall rains.

The experimental results clearly show that while it is not advisable or desirable to attempt to plant until conditions are favorable, yet the crop should be put in as early as conditions will permit, in order to secure the maximum vegetative growth or maximum yield of seed.

Obviously the best time to plant will vary with the locality and to some extent with the season. In the Sacramento and San Joaquin Valley, the optimum time is from the latter part of April to the middle of May, while in the warm sections, such as the Imperial Valley, plantings may be done somewhat earlier. A good guide to follow is to plant ten days to two weeks after the optimum date for planting such a crop as Milo maize or Egyptian corn, or a little later than one would naturally plant cowpeas.

Method and Rate of Seeding.—Under normal conditions, it is better to plant mat beans in rows like common beans, although they may be seeded in a close drill like grain. The early growth of the plants is rather slow, and on land that is weedy, the weeds may choke out much of the crop before it becomes established, unless the crop is planted so that some cultivation, if necessary, can be given. The close drilled method should be used only on good clean land and when the crop is to be used for forage or for soil improvement purposes. It appears doubtful, however, if the yield would normally be any greater than from properly spaced rows. Broadcasting is not recommended, as the surface of the soil is usually dry at the time the crop is planted, making it impossible to work the seed into the moist soil, with the result that the stand will be thin and much of the seed wasted.

When seeded in rows the distances between the rows will vary with the soil or the moisture supply. On poor soil, the growth of the individual plants will not be so large, and the rows should be closer together than on good soil, where a normal growth will be made. With a small amount of moisture more space may be necessary than when the moisture is abundant.

In 1923 a number of plots were planted at Kearney Park Station in which the rows were spaced at distances varying from 24 inches to 48 inches apart. At the period of maximum growth a portion of each plot was cut and weighed green, while the remainder of the plot was allowed to mature its seed.

The results of this test are given in table 2:

TABLE 2

SPACING TEST WITH MAT BEAN, KEARNEY PARK, 1923

Distance between rows	Green matter per acre	Yield of seed per acre
Inches	*Tons*	*Pounds*
24	17.91	2077
30	20.81	2614
36	17.91	2384
42	11.85	1619
48	16.37	1557

The greatest tonnage of green material, as well as the highest yield of seed, was obtained from the 30-inch spacing, and subsequent experience would indicate that this is about the optimum distance for normal conditions. Because of our lack of experience with the crop at the time the test was started, the rate of seeding was too light, so that the stand in the rows was too thin. It appears probable that with a heavier stand in the rows, the yield of green material from the wider spacing would have been better as compared with the narrow spacing. On the poor sandy soil previously mentioned, it has

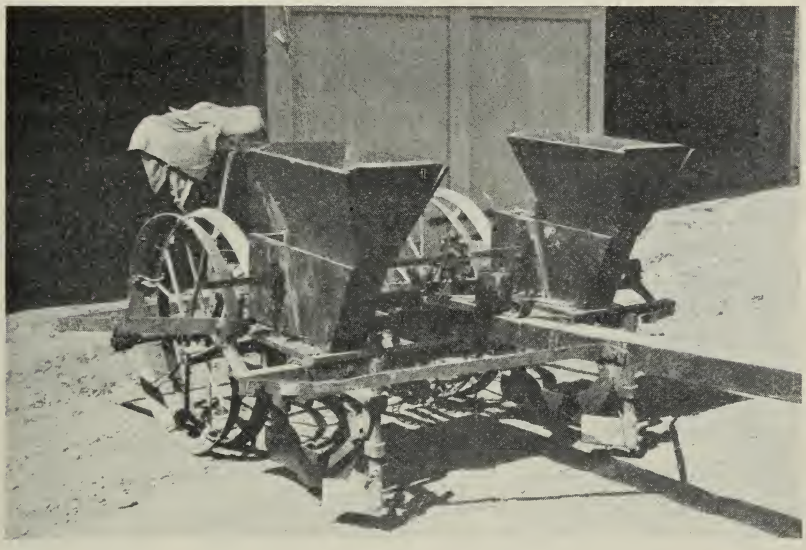

Fig. 4.—Planter equipped with shovels or crowders to open furrows through the dry soil.

been found necessary to space the rows more than 24 to 27 inches apart in order to get the plants to cover the ground completely. The purpose for which the crop is grown may also influence the spacing, or even the method of seeding. If the crop is to be cut for hay it should be planted with rows close together or even in close drills, as the growth will be more erect and easier to handle with the ordinary mowing machinery. On the other hand, for pasture or cover crop purposes and particularly for seed, ample space for normal development of the plants should be provided.

For planting the crop a corn or bean planter (see fig. 4), equipped with plates or sprockets for handling the small seed is most satisfactory. The grain drill may also be used, by stopping up enough of the holes to give proper spacing. Unless the seed bed is even and the mulch shallow, it is not as satisfactory as the other implements.

Owing to the small size of the seed and the fact that it is easily affected by adverse temperature and moisture conditions, the mat bean cannot be planted very deep. One and one-half to two inches is the best depth for average conditions. If planted deeper than this much of the seed is apt to rot or the tender seedlings will be unable to push their way to the surface. It is, of course, necessary to plant deep enough to put the seed in moist soil, but every effort should be made to so prepare the seed bed, that proper moisture conditions may be afforded at the depth mentioned. On unirrigated land, and in the absence of late spring rains, it is often difficult to hold the moisture as near the surface as desired. Frequently the soil dries out to a depth of three or four inches in spite of anything that may be done to prevent it. In such an emergency we have found that the best procedure in planting not only the mat bean, but also other small seeded crops, is to place shovels or crowders (see fig. 4) in front of the planter shoe, which will push the dry soil aside, leaving a shallow trench almost down to moisture. The seed which is planted in the bottom of the trench, is thus placed in moist soil, yet may be only a short distance below the surface. This method is similar to listing, except that the furrows are smaller and shallower. The regular lister may also be used, in extreme cases, but it leaves the field so rough and uneven, that it is not recommended, except when other methods fail.

Rate of Seeding.—The amount of seed required to plant an acre depends mainly upon the method of seeding, whether in rows or in close drills, but is also influenced by other conditions. From limited experience with the crop in the Great Plains, Piper recommends a rate from 5 to 6 pounds to the acre, when planted in rows three feet apart. In India, where the crop is grown extensively, the usual rate of seeding is reported to be 6 to 8 pounds to the acre. In most of our experiments with the crop in 1923 and 1924 a rate of 3½ to 4 pounds per acre has been used when planted in rows 2½ to 3 feet apart. It has been evident, however, that for maximum tonnage, this rate of seeding is too light for any but the most favorable conditions. For seed production, on the other hand, the rate used appears to be about optimum.

When the crop is grown for forage or for cover crop purposes, 6 to 8 pounds of seed should be planted in order to secure a good stand. However, if the seed bed is in good condition, 4 to 5 pounds will be sufficient. When seeded in close drills, 25 to 30 pounds is required to plant an acre.

The seed of the mat bean is rather small, approximately 19,000 seeds to a pound. Seeded at the rate of 5 pounds per acre, in rows 2½ feet apart, the average distance between the seed in the rows will be about one inch. This seems unnecessarily close for a plant like the mat bean that makes so large a growth from a single seed. It must be remembered, however, that the seeds are soft and readily affected by adverse conditions, while the seedlings likewise are tender and easily destroyed, so that even under the most favorable conditions it is probable that rarely more than half of the possible stand survives. Under average or normal conditions, the proportion is probably much less.

While the rate of planting is dependent mainly upon the spacing and method used, the time of planting and the condition of the seed are not without their influence. For early planting a heavy rate of seeding should be employed, as a larger proportion of the seed and seedlings will succumb to cold soil conditions. If the seed bed is in poor condition, more seed will be necessary to get a satisfactory stand than if the seed bed is good.

Care of the Crop.—The purpose for which the crop is grown, and whether or not it is to be irrigated will determine in a measure the cultural treatments necessary during the period of growth. When grown as a dry land crop, little or no cultivation should be necessary, provided the field is free from weeds and the seed bed in good condition. In case the seed bed is loose and open, it will be found advisable to go over the field with a corrugated roller immediately after planting in order to place the seed in more intimate contact with the soil particles. This will hasten germination and improve the stand. The roller, however, should not be used if the soil is wet.

After the plants appear above the ground some cultivation may be necessary, especially if the field is very weedy. During the early stages, the growth of the mat bean is rather slow, and a heavy growth of weeds will lessen the stand or retard the development of the plants. Keeping the field free from weeds is particularly important if the crop is grown for seed or for hay. On the other hand, if grown for green manure or for pasture, as little cultivation should be given as is compatible with the normal development of the plants in order to reduce the cost of production to the minimum. In any event it is easier and cheaper to clean and rid the field of weeds before the crop is put in than to do so after it is up.

Irrigation.—Although the mat bean appears to be fully as tolerant of drought as any legume thus far tested, some irrigation will be usually beneficial or necessary, especially in sections where the annual

precipitation is light. The time of irrigation and the amount of water to apply will vary with conditions and must be determined by the farmer himself.

The most critical period, as far as moisture is concerned, is from the time of planting until the plants are a month or six weeks old. Not that the plants require any more water at this period, but unless the moisture relations are favorable, poor germination and a high mortality of the seedlings are apt to result. If the seed bed is dry to a considerable depth or if the moisture content of the soil is low, the land should be irrigated before the seed bed is prepared. Irrigation at this time will greatly facilitate planting, give a better stand, and maintain normal development of the seedlings until they become well established. Should irrigation be necessary soon after the plants come up, the water should be applied carefully. Otherwise many of the young plants may be scalded out or the soil may crust so badly, that the growth will be severely checked. Later when the plants have attained some size there is little or no danger of injury by irrigation. In fact, the dense mat of vines produced, so effectually shade the ground, that they greatly retard evaporation and prevent crusting of the soil.

The method of applying the water will be influenced mostly by the stage of growth and the purpose for which the crop is grown. When it is grown in orchards and vineyards as a green manure crop, the furrow system of irrigation will be found most satisfactory, because by this system the water can be applied more efficiently. When the bean starts to develop, the furrows must be left open, as cultivation will injure the young plants. The runners, however, will ultimately cover the furrows completely, checking evaporation and rendering cultivation unnecessary. While it is true that such a dense growth will check the flow of water through the furrows somewhat, this effect is not serious.

When the mat bean is grown for hay or seed, on the other hand, the flooding method should be employed, especially during the latter half of the period of growth. The open furrows would leave the field so rough and uneven that serious difficulty might be experienced in attempting to harvest the crop.

HANDLING AND USE

The Mat Bean as a Cover Crop in Orchards and Vineyards.—It appears likely that the greatest immediate use of the mat bean will be as a summer cover crop in orchards and vineyards. Until recently most

orchardists and vineyardists have been averse to using a summer cover crop, believing that any competition with the trees or vines could only be harmful. This attitude, however, is changing. More and more are growers coming to appreciate the fact that the beneficial effect of a leguminous crop more than outweighs the added draft which it may make upon the soil moisture or plant nutrients.

Some interesting observations on the effect of legumes in orchards have been obtained during the recent dry years. In some sections it was observed that orchards which were kept under clean cultivation

Fig. 5.—A rod row showing the creeping habit of mat beans. University Farm, Davis, Calif., Aug. 30, 1924.

suffered severely and were badly damaged by predatory insects, especially red spider, while orchards intercropped with alfalfa or other legumes, showed little or no injury and were much less severely attacked by insects. The reason that the intercropped orchards suffered less may be attributed to the fact that the large roots of the legumes, opened up the soil and allowed the irrigation water to penetrate to a greater depth. Many soils when kept clean cultivated become so hard and compact below the cultivated area, that irrigation water penetrates only with great difficulty, so that tree roots may receive insufficient moisture in spite of the fact that water is applied copiously to the surface. In addition, the cover crop protects the soil from the direct rays of the sun, reduces evaporation and prevents

crusting and baking. It is also probable, although this has not been verified, that nitrification is more rapid in a soil thus protected, than in one exposed to the direct action of the sun and quickly dried out. Again the cover crop reduces radiation from the soil, which together with the high rate of transpiration from the leaves causes a lowering of the temperature in the orchard, and thus protects the trees from extreme heat. In addition to this effect, the use of leguminous cover crops is the only practicable means of supplying the large amount of nitrogenous organic matter necessary to maintain the supply of humus and keep the soil in good tilth.

As a cover crop for vineyards the mat bean appears to possess special merit, since it overcomes many objections usually voiced against the use of the more common summer legumes, such as cowpeas and soybeans. The principal objection to such legumes is that, because of their tall or viny growth, they produce too much shade, interfere with the development of the vines, and the maturity of the fruit, and also that they greatly add to the difficulty of harvesting the grape crop. The mat bean, however, because of its low dense, prostrate growth and non-twining habit, does not shade and interfere with the growth of the vines or the development of the fruit. It is, in fact, a cover crop in the true sense of the word, forming a dense vegetative cover, which seldom attains a height of more than 12 to 14 inches, so that it does not interfere with the growth of the vines nor does it seriously hamper the harvesting of the crop.

In addition to improving the physical and biological condition of the soil, the use of a summer cover crop, such as the mat bean, may exert another beneficial effect, especially upon the light sandy soil on which many of the vineyards are located. On such soil the intense radiation of heat may cause the vines to sunburn severely. A good vegetative cover is reported in many cases to greatly reduce or even entirely prevent such injury. The coloring of the grapes is also said to be improved in many sections by maintaining a soil cover.

As stated previously, when grown in orchards and vineyards, it will be found more economical, as well as more satisfactory generally, to grow the mat bean in rows rather than broadcast or in close drills. The irrigation furrows can then be run between the rows and the water applied without interference. For the best results, however, the rows should be close enough together, so that the runners will completely cover the intervening space. Cultivation after irrigation would, of course, have to cease when the runners cover the ground, but the vegetative cover will serve just as effectively in checking evaporation, and preventing baking of the soil, so that cultivation is unnecessary.

It has, in fact, frequently been observed, that after irrigation the surface of the soil under the plants will remain moist almost indefinitely.

The mat bean may be plowed under or worked into the soil at any time that suits the convenience of the grower, but the largest amount of vegetative matter will be obtained only if the crop is allowed to grow until it practically reaches maturity. For most sections this will usually be about the middle to the latter part of September, and will be indicated by a yellowing of the lower leaves, or approaching maturity of the seed pods.

The actual amount of material which will be available to turn under will, of course, vary with conditions, but in general it may be said, that in those sections to which the mat bean is adapted, the yield will compare favorably with that of any of the more common summer legumes. A rather extensive test was made at the Kearney Park Station, in 1923, in which the mat bean was grown in comparison with some varieties of cowpeas and soybeans, both with and without irrigation. All the legumes were planted in rows three feet apart and otherwise treated as nearly alike as possible. The results are given in table 3.

TABLE 3

YIELD OF GREEN MATTER PER ACRE, OF MAT BEAN, COWPEAS, AND SOYBEANS, KEARNEY PARK, 1923

Legume	Yield of green matter, tons per acre	
	With irrigation	Without irrigation
Mat bean	17.91	24.3
Cream cowpea	13.55	22.3
Victor cowpea	.....	22.3
Columbia cowpea	.....	22.5
Otoo Tan soybean	15.49	.....
Wilson Five soybean	.....	14.7
Virginia soybean	.....	15.5

In both cases the mat bean produced a heavier tonnage than any of the other legumes. All legumes produced a higher yield on the unirrigated than on the irrigated plots, which was doubtless partly due to the fact that the seed bed was in better condition and a better stand was obtained. The treatment of the land may also have influenced the growth and yield.

In other tests, yields of from 10 tons to more than 26 tons have been obtained, depending upon the stand, method of planting, and other factors. The yield which might be obtained by the grower will obviously vary with local conditions, but any good agricultural soil should produce at least 15 to 20 tons, and under good conditions even more. Analyses have shown that, at the stage of maximum growth, about one-fifth of the green weight is dry matter, so that the turning under of a 15 to 20-ton crop would add to the soil 3 to 4 tons of organic matter. In addition, of course, a considerable quantity of organic matter is supplied by the roots, and this is especially important, since it is distributed through a large volume of soil and aids materially in keeping the soil open and receptive of moisture.

The addition of organic matter to the soil in the form of cover crops is particularly advantageous, since it is succulent, decays quickly, and if high in nitrogen, as is the mat bean, has an immediate stimulating effect on nitrification, rather than a depressing effect as is usually the case when highly carbonaceus material is added. Analysis by Goss shows that the vegetative portion of the plant (leaves and stems) contain on an average 2.72 per cent nitrogen. In other words, a 15 and 20-ton crop would add respectively 163 and 217 pounds of nitrogen to the soil in a form which will quickly become available to the crop.

Since the mat bean makes a very dense mat of fine, leafy vines, some difficulty may be experienced in plowing it under, unless it is first thoroughly chopped up. The growth should first be gone over a couple of times with a sharp disc, after which it can be plowed under without difficulty. Disking has the further advantage that it enables the organic matter to be more thoroughly incorporated with the soil, in which condition it will decay more quickly.

The Use of the Mat Bean on Fallow.—As the mat bean is tolerant of drought it may find considerable use as a soil improvement crop, or better still, as a combination soil improvement and forage crop on a considerable acreage of land, which is now handled annually as fallow. It is generally recognized that fallowing has many undesirable features, and that it would be far better if some rotation crop could be found which would return some revenue to the farmer and help keep the soil in a productive condition. As yet, however, such crops have not been available. In spite of the fact that frequent fallowing rapidly reduces the organic matter content of the soil, and destroys its physical condition, it has so far been the only practical means of keeping the land free from weeds and diseases and maintaining productivity on the vast areas of unirrigated land, a large portion of which is cropped to grain. Winter cover crops have been used to a limited extent, and

while the yield of grain is usually higher following a good cover crop, than after the fallow, the cost of producing the cover crop is rather high, and, in most cases, the returns have not justified the added labor and expense. As yet, summer legumes have been used in the place of fallow to a limited extent only, but the results from such a practice have invariably shown that grain following a crop such as beans will do better than after bare fallow.

This has been the experience even for sections where the rainfall is comparatively light. The exact cause of the beneficial action has not yet been determined. It is probable, however, that part of the benefit is due to the large deep penetrating root, which tends to open up the soil and thus improve its physical condition. In addition, the roots and refuse left from the legumes, which are rich in nitrogen, supply a considerable quantity of material readily acted upon by the nitrifying organism, thus increasing the available nitrogen in the soil. The nitrogen gathering bacteria on the roots of the legumes further add to this supply, to the benefit of the following cereal crop. The shading of the soil by the vegetative cover must tend to reduce oxidation and evaporation and thus help maintain the soil in better condition for the succeeding crop. Only a few varieties of our common beans, however, are adapted to use on fallow, and most of these are used principally for human consumption. It is very unlikely therefore that these varieties will be planted on any considerable acreage of fallow, as a great increase in production would soon glut the market and render the product valueless. What is needed is a crop which has a wider and more general use. Of all the legumes thus far tried, the mat bean comes nearest to meeting this condition, since it makes an excellent forage at all stages of growth, and may be used either for pasture or hay. In the type of farming where the fallow is ordinarily employed, it will probably be of greatest value if used as a pasture crop. Planted on fallow, the latter part of April or early in May, the crop would have attained its maximum growth and be ready to feed off in the early fall, when the flocks and herds are being returned from the ranges and at a time when feed is in great demand. It would provide a valuable supplement to the dry stubble pasture usually relied upon to carry the stock through the trying fall period, and the grower should have little difficulty in disposing of the growth at a profit. The mat bean can also be cut for hay to be used as feed later in the season; but, as far as the benefit to the land is concerned and the effect on the succeeding crop, pasturing will probably be the more beneficial. Used in either manner, it would be a distinct and valuable addition to the agriculture of the unirri-

gated region, since it would add a small profit and, at the same time, increase the yields of grain by its beneficial effect on the soil.

After the legume has been pastured off or removed as hay, a thorough disking is all that is necessary to prepare the land for grain.

In growing mat bean on unirrigated land it is particularly important that the field be free from weeds and that the seed bed be well prepared. The corn or bean planter fitted with the proper plates, is the best implement for planting the crop, which should be drilled in rows 2½ to 3 feet apart, using 6 to 7 pounds of seed per acre. Since it cannot safely be planted in most sections until about the first of May, at which time the soil may be dry to a depth of several inches, a furrow opener should be placed in front of the planter shoe, so that the seed will be placed in moist soil without being covered too deep. Even in the absence of late spring rains, it will usually be possible to get a good stand by this method. One or two cultivations to keep the weeds in check, given while the plants are small, may in many instances be found advantageous, but with a clean field and a well prepared seed bed, even this should be unnecessary.

USE OF THE MAT BEAN FOR FORAGE

Use as Pasture.—As a forage crop, the mat bean will probably find its greatest use as a fall pasture, because it is at its best at a period when feed is usually scarce and in great demand. Compared with other more common legumes, such as the cowpea and the soybean, the mat bean has several advantages as a forage crop. It is very tolerant of drought, and when once established will continue to grow even under very trying conditions. It also has a rather indeterminate period of growth, the vines and leaves remaining green even after most of the seed is ripe, until checked by cold weather. Furthermore, it is very palatable and is apparently relished by all classes of livestock, while some of our other legumes, such as sweet clover and cowpeas, are not readily eaten in the green state.

The amount of pasturage which a given area will provide, will, of course depend upon the stand and growth which is obtained. To secure some information as to the pasture value of the mat bean, a one-tenth acre plot was pastured to sheep at the Davis Station in the fall of 1924. Six lambs weighing from 75 to 90 pounds each, were placed on the plot and remained for a period of five days. From the start they consumed the new feed greedily. On the fifth day a rain occurred, and the lambs were removed to prevent tramping and puddling of the soil. At this time they had consumed the larger part of the vegetation

but sufficient feed still remained on the plot to have sustained the small flock for at least two days more. This plot was planted the middle of June, and the growth was not as large as would have been obtained from an earlier planting, but was about what could normally be expected under average conditions in the Sacramento and San Joaquin Valleys. On the basis of this test, one acre would provide sufficient feed to sustain six sheep for a period of about two months.

As emphasized in the previous section, if grown upon even a portion of the vast areas which are fallowed annually, it will not only increase the production of the land, but will provide a large amount

Fig. 6.—A carpet of mat bean plants, Kearney Park, Calif. Mung beans in the background. September, 1923.

of feed which can be used to advantage as pasture for livestock returning from the range. In many seasons the fall is a trying period. Because of a shortage of feed, stock often lose much of the weight that they had made on the range during the summer. This loss could be prevented in large measure by crops of this character. Furthermore, if a permanent and profitable type of agriculture is to be maintained upon much of our unirrigated land, a more diversified type of farming must be developed, and annual legumes of high forage value, such as the mat bean, will, without question, play an important part in such development.

While the mat bean as a pasture crop finds its greatest use on unirrigated land, it may also be used to advantage on the more diversified irrigated farms as an emergency pasture or as a supplement to alfalfa, in case the latter is inadequate to meet the needs for both

hay and pasture. Since it is an annual and can be worked into almost any rotation, it may be used as the need for more feed arises. It can be used as a second crop to follow grain, hay, or any other winter growing annual. Used as a component part of the cropping scheme, it will materially increase the annual production of high quality forage, and thus enable the farmer to maintain upon a given area more livestock than would otherwise be possible.

When the mat bean is used for pasture the method of planting may be varied according to local conditions, and the grower will soon learn which method of planting to employ in order to get the best results in his particular section. It may be pastured at any stage of growth, but the largest amount of feed will be obtained if pasturing is delayed until the plants have practically completed their development, which normally occurs about the first to the middle of September. When necessary, pasturing may be started as early as the first of August, but in any case it should be as light as possible. At this time, the plants are making their most rapid growth, and if grazed too heavily the growth will be checked, and the total feed correspondingly reduced.

Use for Hay.—The mat bean makes excellent hay if cut while the plant is still in a vigorous stage of growth, or about when the first pods are ripening. It has several advantages over most other annual legumes, in that the stems are fine and the leaves do not shatter off readily when cured. In fact, our observations indicate that few legumes retain their leaves as well in the cured state as does the mat bean. In addition, the hay is relished by animals, and has a feeding value practically equal to alfalfa hay.

The chief objection to the mat bean as a hay crop is that, because of its prostrate habit of growth, it is rather difficult to mow. This difficulty is more pronounced if the stand is thin and the rows wide apart, as the vines then have a tendency to lie close to the ground. For hay purposes, therefore, it is better to plant the rows closer together or to seed in close drills, as crowding the plants forces a more upright growth, and makes the hay easier to harvest. Mowing can also be facilitated by fitting the mower with extension guards and a special rod lifter, such as is often used in cutting clover for seed. This devise lifts the vines just ahead of the sickle, so that most of them at least will be cut off. After the crop has been mowed, it should remain in the swath until the leaves are thoroughly wilted, and then raked into windrows. It should be left in the windrows from twelve to twenty-four hours, and then placed in small cocks to complete the curing process. The time required to cure the hay will vary from two to four days, depending on weather conditions. Because of the fine-

ness of the vines, however, the mat bean cures more readily than the coarser stemmed legumes, such as cowpeas or soybeans. Curing should continue until the stems lose their toughness and become somewhat brittle, at which stage it may be safely stacked.

The yield of hay which may be obtained will obviously depend on a number of different factors. The stand will always have an important bearing on the yield. An early planted crop will nearly always make a larger growth and heavier yield than one planted late. The method of planting may also influence the yield, but this in turn will vary with the locality. In our experiments to date, vegetative yields have all been determined on the green basis, but from this we can readily calculate the approximate yield of hay which would have been obtained. Analyses show that about one-fifth of the green weight is dry matter, but since the hay will contain normally about 15 per cent of water, the yield of hay will be about one-fourth of the green weight. In our tests the yield of green material has varied from 9 to 26 tons per acre, which is equivalent to 2¼ to 6½ tons of hay or slightly less, deducting for normal field losses. On an average, a yield or 3 to 4 tons per acre can reasonably be expected, which compares favorably with that obtained from other annual hay crops.

Composition.—Few analyses of the mat bean plant as forage are available. The only analyses at hand are, one of the green fodder reported by Ghosh[5] from India, and two on air-dried material from crops grown at Davis in 1924, one of the latter by Harold Goss of the Division of Nutrition and the other by B. A. Madson. These analyses are given in table 4. For comparison, analyses of alfalfa, cowpeas, and soybeans reported by Henry and Morrison are included.

TABLE 4

COMPOSITION OF MAT BEAN, ALFALFA, COWPEAS, AND SOYBEANS—WHOLE PLANT

	Moisture	Protein	Fat	Ash	Crude fiber	Nitrogen free extract
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Mat bean, Ghosh	50.00	8.07	.....	8.91	4.25	28.77
Mat bean, Goss	8.00	17.00	2.80	12.10	19.08	40.37
Mat bean, Madson	3.82	16.75	2.27	17.28	14.35	45.53
Alfalfa hay	8.6	14.9	2.3	8.6	28.3	37.3
Cowpea hay	9.7	19.3	2.6	11.9	22.5	34.0
Soybean hay	8.6	16.0	2.8	8.6	24.9	39.1

In order that a more direct comparison may be obtained, these analyses calculated to a water-free basis are given in table 5.

TABLE 5

COMPOSITION OF MAT BEAN, ALFALFA, COWPEAS, AND SOYBEANS—WHOLE PLANT

	Moisture	Water-free basis				
		Protein	Fat	Ash	Crude fiber	Nitrogen-free extract
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Mat bean, Ghosh	50.00	16.14	.....	17.82	8.50	57.54
Mat bean, Goss	8.00	18.47	3.04	13.15	20.74	44.60
Mat bean, Madson	3.82	17.41	2.36	17.96	15.90	46.37
Alfalfa hay	8.60	16.30	2.51	9.40	30.96	40.83
Cowpea hay	9.70	21.37	2.88	13.17	24.91	37.67
Soybean hay	8.60	17.50	3.06	9.40	27.24	42.80

Attention is called to the fact that the composition of the mat bean compares favorably with that of alfalfa and other legumes. Its protein content is approximately the same or a little higher than that of alfalfa and a little less than that of cowpeas. The ash content is abnormally high, but in connection with the analysis from India, it was pointed out that about one-half of the ash was sand or silica; a portion of which was due to sand or soil adhering to the plant, and the same was doubtless true to a greater or less extent with the other samples. On the basis of composition it should compare favorably with other legumes as a forage. Its actual value, however, can be determined only by careful feeding tests.

SEED PRODUCTION

As the mat bean is an annual, there will be a yearly demand for seed. There is also the possibility that in time the seed will be in demand for purposes other than those discussed. In India, for example, it is used for human food, as are other beans, and is also used to some extent as a feed for animals. The production of good seed is important and should be a profitable undertaking in some sections. It appears from past experience that the mat bean does not set seed in all sections. Some years ago when the crop was first grown experimentally in Texas, it performed very satisfactorily as a forage crop. Interest in it waned, when it failed to set seed, as it was realized that unless seed could be produced abundantly and cheaply it would hold little value as a forage crop. In our experiments with this crop in this state during the past three years, it has produced seed abundantly,

both at the Kearney Park Station, near Fresno, and at the University Farm at Davis. At the Imperial Valley Station, on the other hand, the setting of seed has always been very light. Experience of others corroborate ours, however, that in the Sacramento and San Joaquin valleys, seed can be produced both abundantly and cheaply.

In some respects the seed habits of the mat bean are excellent. Not only does it produce abundantly under favorable conditions, but it holds its seed well, shattering very little even after it is cured and dried. The only difficulty which is apt to be experienced, is that the early fall rains may cause the pods and seed to rot before the crop can be harvested. This difficulty can be avoided to a large extent by

Fig. 7.—Trailers of mat bean plants turned back to expose the masses of pods underneath hidden by the leaves.

planting early, and by harvesting as soon as most of the pods are ripe, or as soon as there is danger from fall rains. Growing the crop for seed does not differ materially in its cultural aspects, from growing it for forage, except that it should be planted early, and the rows should be wider apart and the stand thin, to allow for the full development of the individual plants. It has been our experience that the highest yield of seed is obtained by planting as early as local conditions will permit.

Referring to table 1, it will be noted that the highest yield of seed was obtained from the late April and early May plantings, and there was a rapid decrease in seed productivity with later plantings. The plot planted July 6 produced only one-sixth as much seed as the one planted May 3. While the optimum time for planting will vary slightly with the season and the locality, the best time for most sections appears to be from the first to the middle of May.

In order to get a good seed crop, ample space for the development of the plants is important. It will be noted by referring to table 2, that higher yields of seed were obtained when the crop was planted in rows 30 to 36 inches apart, than when either closer or wider spacing was used. For average conditions, 36-inch spacing is probably the safest. We have also observed that a thick stand or a crowding of the plants in the row tends to reduce seed setting. For this reason a lighter rate of seeding should be employed than when the crop is grown for green manure purposes or for forage. With a good seed bed condition at the time of planting, 3 to 4 pounds per acre is ample, while if the conditions are not so favorable, a slightly heavier rate may be employed.

During the growing season some cultivation should be given to keep down weeds and to maintain the soil in good tilth. If water is available, one or two irrigations to stimulate growth, may also be found advantageous. Otherwise no special care or treatment is necessary.

Harvesting.—The mat bean has a rather indeterminate period of growth, and mature pods, green pods, and blossoms may be found on the plant at the same time. For this reason, the grower must use his judgment as to the best time to harvest. The optimum time is when most of the pods are mature. It is not safe to wait until all the pods are ripe, as there may be some loss from shattering, and there is always the danger of having the crop caught by early rains. If a rain does occur, the crop should be cut as quickly as possible, and the vines turned over to expose the pods to the sun, so that they will dry out as quickly as possible. If this is not done the loss from rotting will be heavy.

The best implement for harvesting the seed crop is a bean cutter, which shears off the plants just below the surface of the ground, throwing two rows together in a single windrow. After cutting, the beans may be left in the windrow until dry enough to thresh, or they may be left until thoroughly wilted and placed in small cocks to complete the curing process. Where threshing is to be done with a stationary outfit, the latter method is to be preferred, as it facilitates handling.

Threshing should be done as soon as the vines and pods are thoroughly dry. The regular bean thresher is the best machine for doing the work, but a grain thresher can also be used by reducing the speed of the cylinder sufficiently to prevent cracking of the seed. When available, the "bean pickup," with which the crop could be threshed directly from the windows, could be used with advantage, as it would greatly reduce the expense and labor of handling.

After threshing, the seed should be stored in a dry place until it is to be planted or placed on the market. Should any quantity of trash or foreign material be mixed with the seed in threshing, it should be cleaned out as quickly as possible, as it will tend to draw moisture, and may cause the seed to heat and spoil.

Yield of Seed.—The yield of seed that may be obtained will vary so greatly with the conditions of growth, that it is hardly safe, as yet, to predict what may be normal expectancy under average conditions. In the experiments at the Kearney Park Station, the estimated yield has varied from 280 pounds per acre to as high as 2614 pounds per acre. Most of the tests, however, have ranged from 1100 to 1600 pounds per acre.

At the University Farm at Davis, in 1924, four one-tenth acre plots were planted to mat bean for seed, the yields from which are given in table 6.

TABLE 6

Mat Bean Seed Production, Davis, 1924

Plot No.	Yield per acre, Lbs.
D–32	630
D–34	880
D–36	650
D–38	700
Average	715±38.2

While the yields were not as high as the average from the Kearney Park station in 1923, they, nevertheless, were very satisfactory, considering the fact that the crop was not planted until June 15th, which experience has shown is too late for the best results.

Use and Composition of the Seed.—As has already been stated, the principal use of the seed in this country will probably be for planting purposes. While in the orient it is used in various ways as human food, it is hardly likely that it will find much demand for that purpose here. The excess over the amount needed for planting and the inferior quality of seed will doubtless be fed to livestock. Unfortunately, we have as yet no information on its feed value. On the basis of its composition given in table 7, it appears to be good feed, especially in small quantities, since it is rich in proteins and carbohydrates. What effect it may have on animals if fed in large quantities is not known, and it should be used sparingly until further information is available. The small size of the seed would lead one to believe that it might prove a valuable feed for poultry.

TABLE 7

COMPOSITION OF MAT BEAN SEED

	Moisture	Protein	Fat	Ash	Crude fiber	Nitrogen-free extract
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Average of 5 foreign analyses	9.62	23.07	.73	4.29	4.02	58.27
Analysis by H. Goss, Mottled seed	10.10	22.63	.82	4.10	5.33	57.02
Analysis by H. Pence, Yellow seed	10.96	23.91	1.12	3.67	.....	60.34(a)

(a) Crude fiber plus nitrogen-free extract.

ENEMIES OF THE MAT BEAN

So far the mat bean has not been attacked to any great extent by serious diseases or insect pests. We have grown it adjacent to beans and other legumes which have been badly infested with red spider and thrip, but the mat bean has not been attacked or injured by these insects. The only pest which has caused trouble is nematodes. For the past two years, the mat bean with other legumes has been grown at Kearney Park, on a piece of sandy land, badly infested with this pest, and some damage has occurred each season. Some of the plants became stunted and turned yellow, others were completely killed, still others showed no effect, although nematodes were present on the roots. In the same field susceptible varieties of cowpeas were almost completely destroyed each season. It would appear, therefore, that in its resistance to this pest, it is about intermediate between the extremely susceptible and the so-called resistant forms of legumes.

The seed is susceptible to the attacks of bean weevil, as is that of other beans. Since the only method of combating this pest is to fumigate the seed in storage, the seed should be examined occasionally, and if weevils are present it should be fumigated, either with carbon bisulphide or cyanide, at such times and as often as is necessary to keep the weevil in check. Seed harvested in the fall will seldom be badly damaged by the next planting season, as the insects do not multiply rapidly during the cool weather of the winter. The greatest damage usually occurs to seed held over more than one season.

LITERATURE

[1] CANDOLLE, A. P. de
1886. Origin of cultivated plants. 345.

[2] CONNOR, A. B.
1910. Report of coöperative forage crop work. Texas Agr. Exp. Sta. Bul. 132:25.

[3] COOKE, T.
1903. Flora of the Presidency of Bombay. 1:378–379.

[4] DUTHIE, J. F. and FULLER, J. B.
1882. Field and garden crops of the North-Western Provinces and Ouhd. pt. 1, 1–87. *22 pl.* Roorkee, India.

[5] GHOSH, A. C.
1917. The fodder pulses, meth, bhringi and mashyem Kalai. Bihar and Orissa Agr. Jour. Patna, India, 5^1:15–47. 14 tab. *5 pls.*

[6] HARZ, C. D.
1885. Landwirthschaftliche Samenkunde. 734.

[7] KENNEDY, P. B., and MADSEN, B. A.
1923. The moth bean. The Fruitman, 3^1:4.

[8] KENNEDY, P. B.
1923. The mung bean—an improver of soils. The Fruitman 3^{10}:3.

[9] KELKAR, R. B. G. K.
1917. Establishment and management of the dairy farm. Dept. of Agr. Bombay, Bul. 86:46.

[10] LEATHER, J. Walter
1901. Indian food grains and fodders. The Agricultural Ledger.
1903. Calcutta. 1901:349; 1903:147.

[11] MOLLISON, J.
1901. Textbook on Indian agriculture. 3:1–283. Bombay.

[12] PIPER, C. V. and MORSE, W. J.
1914. Five oriental species of beans. U. S. Dept. Agr. Bur. of Pl. Ind. Bul. 119: (Professional paper), 1–32, *7 pl.*

[13] PIPER, C. V.
1924. Forage plants and their culture. (Revised edition), 611–612.

[14] SORNAY, P. de
1916. Green manures and manuring in the tropics. 137–138.

[15] WATT, George
1908. Commercial products of India. 879.

STATION PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION

BULLETINS

No.

253. Irrigation and Soil Conditions in the Sierra Nevada Foothills, California.
261. Melaxuma of the Walnut, "Juglans regia."
262. Citrus Diseases of Florida and Cuba Compared with Those of California.
263. Size Grades for Ripe Olives.
268. Growing and Grafting Olive Seedlings.
273. Preliminary Report on Kearney Vineyard Experimental Drain.
275. The Cultivation of Belladonna in California.
276. The Pomegranate.
277. Sudan Grass
278. Grain Sorghums.
279. Irrigation of Rice in California.
280. Irrigation of Alfalfa in the Sacramento Valley.
283. The Olive Insects of California.
285. The Milk Goat in California.
294. Bean Culture in California.
304. A Study of the Effects of Freezes on Citrus in California.
310. Plum Pollination.
312. Mariout Barley.
313. Pruning Young Deciduous Fruit Trees.
319. Caprifigs and Caprification.
324. Storage of Perishable Fruit at Freezing Temperatures.
325. Rice Irrigation Measurements and Experiments in Sacramento Valley, 1914–1919.
328. Prune Growing in California.
331. Phylloxera-Resistant Stocks.
334. Preliminary Volume Tables for Second-Growth Redwood.
335. Cocoanut Meal as a Feed for Dairy Cows and Other Livestock.
339. The Relative Cost of Making Logs from Small and Large Timber.
340. Control of the Pocket Gopher in California.
343. Cheese Pests and Their Control.
344. Cold Storage as an Aid to the Marketing of Plums.
346. Almond Pollination.
347. The Control of Red Spiders in Deciduous Orchards.
348. Pruning Young Olive Trees.
349. A Study of Sidedraft and Tractor Hitches.
350. Agriculture in Cut-over Redwood Lands.
352. Further Experiments in Plum Pollination.
353. Bovine Infectious Abortion.
354. Results of Rice Experiments in 1922.
357. A Self-mixing Dusting Machine for Applying Dry Insecticides and Fungicides.

No.

358. Black Measles, Water Berries, and Related Vine Troubles.
359. Fruit Beverage Investigations.
361. Preliminary Yield Tables for Second Growth Redwood.
362. Dust and the Tractor Engine.
363. The Pruning of Citrus Trees in California.
364. Fungicidal Dusts for the Control of Bunt.
365. Avocado Culture in California.
366. Turkish Tobacco Culture, Curing and Marketing.
367. Methods of Harvesting and Irrigation in Relation to Mouldy Walnuts.
368. Bacterial Decomposition of Olives during Pickling.
369. Comparison of Woods for Butter Boxes.
370. Browning of Yellow Newtown Apples.
371. The Relative Cost of Yarding Small and Large Timber.
372. The Cost of Producing Market Milk and Butterfat on 246 California Dairies.
373. Pear Pollination.
374. A Survey of Orchard Practices in the Citrus Industry of Southern California.
375. Results of Rice Experiments at Cortena, 1923.
376. Sun-Drying and Dehydration of Walnuts.
377. The Cold Storage of Pears.
379. Walnut Culture in California.
380. Growth of Eucalyptus in California Plantations.
381. Growing and Handling Asparagus Crowns.
382. Pumping for Drainage in the San Joaquin Valley, California.
383. Monilia Blossom Blight (Brown Rot) of Apricot.
384. A Study of the Relative Values of Certain Succulent Feeds and Alfalfa Meal as Sourses of Vitamin A for Poultry.
385. Pollination of the Sweet Cherry.
386. Pruning Bearing Deciduous Fruit Trees.
387. Fig Smut.
388. The Principles and Practice of Sun-drying Fruit.
389. Berseem or Egyptian Clover.
390. Harvesting and Packing Grapes in California.
391. Machines for Coating Seed Wheat with Copper Carbonate Dust.
392. Fruit Juice Concentrates.

CIRCULARS

No.

87. Alfalfa.
113. Correspondence Courses in Agriculture.
117. The Selection and Cost of a Small Pumping Plant.
127. House Fumigation.
129. The Control of Citrus Insects.
136. *Melilotus indica* as a Green-Manure Crop for California.
144. Oidium or Powdery Mildew of the Vine.
151. Feeding and Management of Hogs.
152. Some Observations on the Bulk Handling of Grain in California.

No.

154. Irrigation Practice in Growing Small Fruit in California.
155. Bovine Tuberculosis.
157. Control of the Pear Scab.
160. Lettuce Growing in California.
164. Small Fruit Culture in California.
165. Fundamentals of Sugar Beet Culture under California Conditions.
166. The County Farm Bureau.
167. Feeding Stuffs of Minor Importance.
170. Fertilizing California Soils for the 1918 Crop.

No.
173. The Construction of the Wood-Hoop Silo.
178. The Packing of Apples in California.
179. Factors of Importance in Producing Milk of Low Bacterial Count.
184. A Flock of Sheep on the Farm.
190. Agriculture Clubs in California.
199. Onion Growing in California.
202. County Organizations for Rural Fire Control.
203. Peat as a Manure Substitute.
209. The Function of the Farm Bureau.
210. Suggestions to the Settler in California.
212. Salvaging Rain-Damaged Prunes.
214. Seed Treatment for the Prevention of Cereal Smuts.
215. Feeding Dairy Cows in California.
217. Methods for Marketing Vegetables in California.
220. Unfermented Fruit Juices.
228. Vineyard Irrigation in Arid Climates.
230. Testing Milk, Cream, and Skim Milk for Butterfat.
231. The Home Vineyard.
232. Harvesting and Handling California Cherries for Eastern Shipment.
233. Artificial Incubation.
234. Winter Injury to Young Walnut Trees during 1921–22.
235. Soil Analysis and Soil and Plant Interrelations.
236. The Common Hawks and Owls of California from the Standpoint of the Rancher.
237. Directions for the Tanning and Dressing of Furs.
238. The Apricot in California.
239. Harvesting and Handling Apricots and Plums for Eastern Shipment.
240. Harvesting and Handling Pears for Eastern Shipment.
241. Harvesting and Handling Peaches for Eastern Shipment.
242. Poultry Feeding.
243. Marmalade Juice and Jelly Juice from Citrus Fruits.
244. Central Wire Bracing for Fruit Trees.
245. Vine Pruning Systems.
247. Colonization and Rural Development.
248. Some Common Errors in Vine Pruning and Their Remedies.
249. Replacing Missing Vines.
250. Measurement of Irrigation Water on the Farm.
251. Recommendations Concerning the Common Diseases and Parasites of Poultry in California.
252. Supports for Vines.
253. Vineyard Plans.
254. The Use of Artificial Light to Increase Winter Egg Production.
255. Leguminous Plants as Organic Fertilizer in California Agriculture.

No.
256. The Control of Wild Morning Glory.
257. The Small-Seeded Horse Bean.
258. Thinning Deciduous Fruits.
259. Pear By-products.
260. A Selected List of References Relating to Irrigation in California.
261. Sewing Grain Sacks.
262. Cabbage Growing in California.
263. Tomato Production in California.
264. Preliminary Essentials to Bovine Tuberculosis Control.
265. Plant Disease and Pest Control.
266. Analyzing the Citrus Orchard by Means of Simple Tree Records.
267. The Tendency of Tractors to Rise in Front; Causes and Remedies.
268. Inexpensive Lavor-saving Poultry Appliances.
269. An Orchard Brush Burner.
270. A Farm Septic Tank.
271. Brooding Chicks Artificially.
272. California Farm Tenancy and Methods of Leasing.
273. Saving the Gophered Citrus Tree.
274. Fusarium Wilt of Tomato and its Control by Means of Resistant Varieties.
275. Marketable California Decorative Greens.
276. Home Canning.
277. Head, Cane, and Cordon Pruning of Vines.
278. Olive Pickling in Mediterranean Countries.
279. The Preparation and Refining of Olive Oil in Southern Europe.
281. The Results of a Survey to Determine the Cost of Producing Beef in California.
282. Prevention of Insect Attack on Stored Grain.
283. Fertilizing Citrus Trees in California.
284. The Almond in California.
285. Sweet Potato Production in California.
286. Milk Houses for California Dairies.
287. Potato Production in California.
288. Phylloxera Resistant Vineyards.
289. Oak Fungus in Orchard Trees.
290. The Tangier Pea.
291. Blackhead and Other Causes of Loss of Turkeys in California.
292 Alkali Soils.
293. The Basis of Grape Standardization.
294. Propagation of Deciduous Fruits.
295. The Growing and Handling of Head Lettuce in California.
296. Control of the California Ground Squirrel.
297. A Survey of Beekeeping in California; The Honeybee as a Pollinizer.
298. The Possibilities and Limitations of Coöperative Marketing.
299. Poultry Breeding Records.

The publications listed above may be had by addressing

College of Agriculture,
University of California,
Berkeley, California.

20*m*-11,'25